Global Mapping of Near-inertial and Tidal Internal Wave Propagation

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LONG-TERM GOALS

The long-term goal is to understand the magnitude and distribution of internal-wave propagation and internal-wave-induced mixing.

OBJECTIVES

- To use detect energy-flux associated with low-mode near-inertial and tidal propagation in moored current meter data at as many locations as possible.
- To determine the degree to which energy-flux divergences (and therefore sites of enhanced dissipation) can be determined from this analysis.
- To compute time-averaged spatial maps of near-inertial, internal-tidal and mesoscale energy from TOPEX/ POSEIDON altimetry, drifters, current meters and ADCP tracks.
- To determine, within the context of Peter Muller's Internal Wave Action Model (IWAM, also supported by ONR), the extent to which these findings are consistent with existing internal-wave propagation theories.
- To use large-scale and regional atmospheric models to examine the high-latitude and small-scale reliability, interannual variability, and convergences/divergences in the wind energy flux maps computed by Alford (2001).

APPROACH

To accomplish the goal stated above, one could measure microstructure at every location on the planet (impossible). The alternate approach taken here is to map the sources of internal waves already begun by Egbert and Ray (2000) for tidal input, and by Alford (2001) and Toshi (2002) for near-inertial input, and to follow their subsequent propagation. Divergences in the internal-wave energy flux field must then correspond to energy sinks, i.e., regions of enhanced mixing.

I have begun by computing the energy flux in the near-inertial and tidal bands using historical moored records of velocity and temperature. Hundreds of records have been collected over the years. Kunze et al (2002) showed that energy-flux could be computed from full-depth records of velocity and

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isopycnal displacement. The approach taken here is first to band-pass moored records of velocity and temperature to either near-inertial or tidal frequencies. Isopycnal displacement is then estimated from temperature records via $\eta=T'/(\delta T/\delta z)$. Time series of velocity and displacement for the first two baroclinic modes are estimated from the moored records using a least-squares fit. (Experience is showing that not all mooring geometries are equally capable of resolving the first two modes; careful sensitivity analysis will be required to address these and other sensitivity issues.) The pressure anomaly, p', is then estimated from the full-depth modal profiles of η according to the methods of Kunze et al (2002), and the vector energy-flux computed from $\mathbf{F}=\langle\mathbf{u}'p'\rangle$, where <> indicate averaging over a wave period.

WORK COMPLETED

Funding for this project began May 2002. Since that time, Ph.D. student Maya Whitmont has arrived at APL/UW and has begun work analyzing historical moored records from the Oregon State Buoy group. She has examined hundreds of records for quality, and processed them into uniform format. Sixty-five records were selected for the initial flux calculation presented here. Then, I used these records to compute the fluxes in the lowest two modes in the inertial and M_2 bands. A paper describing the initial findings for the near-inertial band, summarized in the next section, has been submitted to Nature (Alford 2002).

RESULTS

The results of the first 65 moorings in the near-inertial band are shown in Figure 1. Several observations are immediately apparent:

1. Predominant propagation is toward the equator, consistent with generation by wind at the local inertial frequency and subsequent propagation to regions of lower f. This has profound implications for our understanding of the global internal-wave field, and is in contrast with the model of Fu (1981), which attempted to explain the inertial peak By *poleward* propagation of super-inertial internal waves.

2. The magnitudes are of order 1 kWm^{-1}, the same order of magnitude as measured tidal fluxes (e.g. Ray and Cartwright, 2001). Therefore, near-inertial waves appear as important as the tides in transporting energy horizontally.

3. The fluxes are of the correct order of magnitude to account for a substantial percentage of near-inertial input (shown in color). Therefore, assuming that all energy input is dissipated at the source is not justified. Propagation is, in general, away from source regions, as expected.

IMPACT/APPLICATIONS

The observed tendency for near-inertial energy flux to be directed toward the equator is extremely important, confirming the idea of wind as a major source of internal waves. The observation of substantial fluxes in the near-inertial band is a major step toward understanding internal-wave-generated mixing. As the database of observations grows, divergences in the energy flux maps should point to regions of high dissipation, guiding future observational efforts.

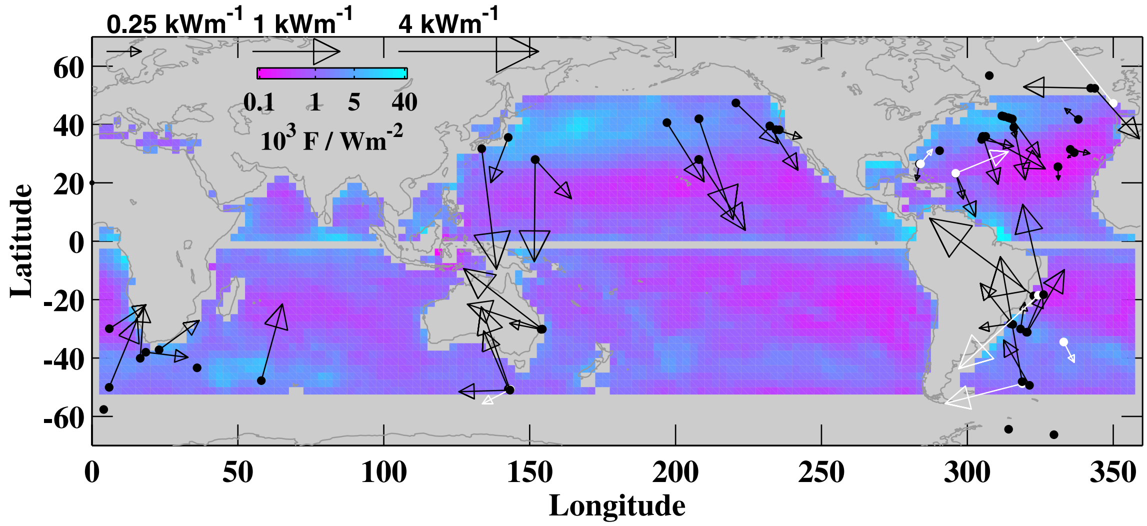

Figure 1: (Color) Annual-mean energy-flux from the wind to near-inertial mixed-layer motions from Alford (2001). The color scale is logarithmic and is indicated at upper left. Depth-average near-inertial energy-flux vectors for modes 1 and 2 are plotted from 65 historical moored records. The length of each arrow Is logarithmic, with references indicated at upper left. The few instances of poleward propagation are plotted in white. The majority of records show equatorward energy propagation, consistent with generation by midlatitude travelling storms and subsequent beta-plane propagation.

TRANSITIONS

Maya Whitmont's Ph.D. thesis will continue these analyses, attempting to form a global view of the energy fluxes to, through and out of the internal-wave field.

Peter Muller is enthusiastic about the incorporation of these data into his ONR-funded Internal Wave Action Model (IWAM). As the reliability of this model grows, it may be useful in filling in data gaps evident in Figure 1.

RELATED PROJECTS

None to report.

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